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# IMPACT OF ENERGY RENOVATION ON INDOOR AIR QUALITY IN MULTIFAMILY DWELLINGS IN SLOVAKIA

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## INTRODUCTION

Buildings are responsible for a substantial portion of global energy consumption. Most of the multifamily residential buildings in Slovakia built in the 20$^{th}$ century do not satisfy the current requirements on energy efficiency. Nationwide remedial measures are taken to improve the energy efficiency of these buildings and reduce their energy consumption (Földváry et al., 2013). However, since the impact of these measures on the indoor air quality is rarely considered, they often compromise indoor air quality due to decreased ventilation and infiltration rate. Poor indoor air quality in dwellings may have adverse effect on the health and comfort of the occupants (Bluyssen, 2009). The objective of this study was to evaluate the impact of energy renovation on the indoor environmental quality of multifamily apartment buildings.

## METHODS

The indoor environmental quality of two identical apartment buildings in Slovakia was compared during the winter season. One of the buildings has been renovated (thermally insulated façade, replacement of old windows for new energy efficiency windows, hydraulic balancing of the heating system), while the other one is in its original condition. Natural ventilation is used in both residential buildings. Exhausts are used only in sanitary rooms (bathrooms and toilets).

Both objective measurements and subjective evaluation using questionnaire have been performed. Temperature, relative humidity and the concentration of $CO_2$ were measured in the bedrooms of the apartments using a HOBO U12-012 data logger (Onset Computer Corp.,USA) and CARBOCAP $CO_2$ monitors (GMW22, Vaisala, Finland). The data were recorded in 5 minutes intervals in period from 2$^{nd}$ to 8$^{th}$ January 2014 in the renovated multifamily dwelling and from 9$^{th}$ to 15$^{th}$ January 2014 in the residential dwelling in original condition. The locations of the instruments were selected with respect to the limitations of the carbon dioxide method (Persily, 1997). There are 18 apartments in each building in total, two on each floor. These apartments are facing either north-east (Type 1) or south-east (Type 2). The measurements and the questionnaire survey have been performed in 15 apartments in the renovated building and in 11 apartments in the original building.

The questionnaire contained questions about basic information on the occupants, building characteristics, occupant behavior and habits, sick building syndrome symptoms and

occupants' perception of indoor air quality and thermal environment. The occupants of the renovated building were also asked whether they have altered their ventilation habits after renovation. In what follows, we present the results of the $CO_2$ measurements, the occupants' perception of indoor air quality and their ventilation habits.

## RESULTS AND DISCUSSION

We compared $CO_2$ concentrations in pairs of apartments that have identical location within the two buildings. The average $CO_2$ concentrations were slightly higher in the apartments located in the renovated building compared to those in the building in original condition (Table 1). The largest differences in $CO_2$ concentration are between the north-facing apartments located on the ground floor and on the 6$^{th}$ floor.

Table 1. Comparison of the average $CO_2$ concentrations in the apartments.

| Floor | Apartments | $CO_2$ concentration (ppm) Original building | $CO_2$ concentration (ppm) Renovated building | Difference (%) |
|---|---|---|---|---|
| Ground floor | Type 1 | 1318 | 1986 | 34 |
| | Type 2 | 850 | 858 | 1 |
| 3$^{rd}$ floor | Type 2 | 1109 | 1288 | 14 |
| 4$^{th}$ floor | Type 1 | 1726 | 1807 | 5 |
| 6$^{th}$ floor | Type 1 | 1280 | 2813 | 55 |
| | Type 2 | 534 | 802 | 33 |

The subjective evaluations of indoor air quality indicated a clear difference between the two buildings. Figure 1 summarizes the occupants' answers to the question "How unpleasant do you think the indoor air quality is in your bedroom during night/in the morning?". The possible answers were from 1 - perceived air quality was not a problem, to 6 - poor indoor air quality. While the residents in the non-renovated building did not indicate severe problems with perceived air quality, a greater fraction of the occupants were dissatisfied with it in the renovated building.

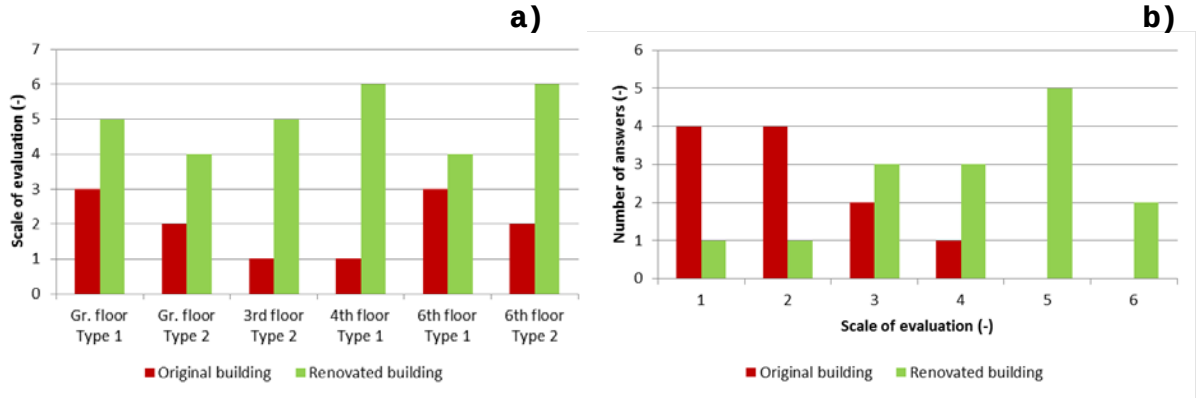


Figure 1. a) Subjective evaluation of the indoor air quality by occupants in corresponding pairs of apartments by location in the two buildings (6+6 apartments); b) Summary of subjective evaluation of indoor air quality by one occupant in each of the investigated apartments (26 in total) in the two buildings

Energy renovations of apartment buildings may directly lead to lower ventilation rates and higher concentrations of indoor pollutants (Pustayová, 2013). This is especially the case when

the occupants do not alter their ventilation habits after renovation of the building. In the present study only 27% of the occupants indicated that they ventilate more often than before renovation. This may further indicate generally poorer air quality in the reconstructed apartment building. Unless measures are taken against decreasing ventilation rates during the reconstruction process (e.g. installing exhaust ventilation or mechanical ventilation), the occupants need to open windows more frequently in order to decrease $CO_2$ concentrations and improve the indoor air quality to the level they were before reconstruction. The limitation of the study is its small sample size. Validation of the results on larger sample size is warranted. The study is ongoing and additional results will be available in the near future.

## CONCLUSION

The current study indicates that large-scale renovations of apartment buildings in Slovakia may reduce the quality of the indoor environment in a substantial fraction of the apartments. Energy reconstruction without consideration of the indoor environmental quality can adversely affect the indoor environment of the apartments.

## ACKNOWLEDGEMENT

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